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Agricultural Machinery – Peanut Sheller – Methods of Test

DEPARTMENT OF TRADE & INDUSTRY PHILIPPINES

BUREAU OF PRODUCT STANDARDS

National Foreword

This Philippine Agricultural Engineering Standards PAES 221:2004, Agricultural Machinery – Peanut Sheller – Methods of Test was approved for adoption as a Philippine National Standard by the Bureau of Product Standards upon the recommendation of the Agricultural Machinery Testing and Evaluation Center.

CONTENTS

ANNEXES

Agricultural Machinery – Peanut Sheller – Methods of Test

1 Scope

This standard specifies the methods of test and inspection for power-operated peanut shellers. Specifically, it shall be used to:

1.1 verify the dimensions, weight, and other technical data of the peanut sheller submitted by the manufacturer/dealer

1.2 determine the performance of the machine;

1.3 evaluate the ease of handling and safety features;

1.4 determine shelling losses and quality of shelled peanuts through laboratory analysis; and

1.5 prepare a report on the results of the tests

2 References

The following normative document contains provisions, which, through reference in this text, constitute provisions of these standards:

PAES 103:2000 Agricultural Machinery – Method of Sampling

PAES 220:2004 Agricultural Machinery - Peanut Sheller- Specifications

3 Definitions

For the purpose of this standard, the following definitions shall apply:

3.1
blower loss
ratio of the weight of kernel blown with the shell by the sheller fan to the total kernel input expressed as percentage by weight

3.2
cracked kernel
kernel which shows signs of fissures or fractures

3.3
input capacity
weight of input materials per unit loading time into the hopper/intake pit, expressed in kilogram per hour

3.4
kernel
edible part of peanut

3.5
kernel-pod ratio
ratio of the weight of kernel to the weight of the pod, expressed as percent

3.6
main kernel outlet
outlet at which shelled kernel move out of the machine

NOTE In the case of the machine with no separating devise or in case of machine with blowers, shelled and unshelled and partially-shelled pods also come out.

3.7
mechanically damaged kernels
broken kernels and/or scratched as a result of shelling operation

3.8
net cracked kernel
difference between the percent cracked kernel taken before and after the shelling operation

3.9
output capacity
weight of the shelled kernel received at the main kernel outlet per unit time, expressed in kilogram per hour

3.10
overall height
distance between the horizontal supporting surface and the horizontal plane touching the uppermost part of the shelling unit

NOTE All parts of the shelling unit projecting upwards are contained between these two planes.

3.11
overall length
distance between the vertical planes at the right angles to the median plane of the shelling unit and touching its front and rear extremities

NOTE All parts of the shelling unit, in particular, components projecting at the front and at the rear are contained between these two planes. Where an adjustment of components is possible, it shall be set at minimum length.

3.12
overall width
distance between the vertical planes parallel to the median plane of the shelling unit, each plane touching the outermost point of the sheller on its respective side

NOTE All parts of the shelling unit projecting laterally are contained between these two planes.

3.13
partially-shelled pod
pod being left with kernels in it after shelling

3.14
pod
unbroken shell with kernel inside

3.15
running-in period
preliminary operation of the machine to make various adjustments prior to the conduct of test until the operation is stable

3.16
separation loss
ratio of the weight of the kernel that comes out of the shelling cylinder with the shell, to the total kernel input expressed as percentage by weight

3.17
shell outlet
outlet at which shells come out of the machine in case of the machine with blower(s)

3.18
shelling efficiency
shelled kernel received at all outlet with respect to the total kernel input expressed as percentage by weight

3.19
shelling recovery
ratio of the weight of the kernel collected at the main kernel outlet to the total kernel input expressed as percentage by weight

3.20
total kernel input
sum of the weight of kernel collected from the main kernel input and the clean kernel from the blower loss, separation loss, unshelled loss and scattering loss

3.21
unshelled loss
ratio of the weight of the kernel that remained in the shell after feeding into the shelling cylinder to the total kernel input expressed as percentage by weight

4 General Conditions for Test and Inspection

4.1 Selection of peanut sheller to be tested

Peanut sheller submitted for test shall be sampled in accordance with PAES 103.

4.2 Role of manufacturer/dealer

The manufacturer shall submit specifications and other relevant information about the peanut sheller and shall abide with the terms and conditions set forth by an official testing agency.

4.3 Role of the representative of the manufacturer/dealer

An officially designated representative of the manufacturer shall operate, adjust, repair, and shall decide on matters related to the operation of the machine.

4.4 Test site conditions

Peanut sheller shall be installed on a stable level ground on a site with sufficient working space, and shall be positioned in such a way that the wind will not blow the shell and other impurities into the clean kernel.

4.5 Test instruments

The instruments to be used shall have been calibrated and checked by the testing agency prior to the measurements. The suggested list of minimum field and laboratory test equipment and materials needed to carry out the peanut sheller test is shown in Annex A.

4.6 Test materials

4.6.1 Sample characteristics

Test materials to be used shall have the following characteristics:

4.6.1.1 Variety : commonly or locally grown

4.6.1.2 Moisture content : 12 % - 14 %, wet basis

However, if the test materials are beyond the recommended characteristics, the manufacturer has the option to pursue the test.

4.6.2 Quantity to be supplied

The amount of test material to be supplied shall be at least 75 % of input capacity of peanut sheller.

5 Test and Inspection

5.1 Verification of the manufacturer's technical data and information

5.1.1 This inspection is carried out to verify the mechanism, main dimensions, materials and accessories of the peanut sheller in comparison with the list of manufacturer's technical data and information.

5.1.2 A plain and level surface shall be used as reference plane for verification of peanut sheller's dimensional specifications.

5.1.3 The items to be inspected and verified shall be recorded in Annex B.

5.2 Performance test

5.2.1 This is carried out to obtain actual data on overall machine performance.

5.2.2 Initial data of the crop conditions such as variety, source, etc. shall be recorded before the test.

5.2.3 Test material to be used

Test materials prepared to be used for the running-in and for each test trial shall be the same.

5.2.4 Running-in and preliminary adjustment

Before the start of the test, the peanut sheller should have undergone running-in period wherein various adjustments of the peanut sheller shall be made according to the recommendation of the manufacturer. (No other adjustments shall be permitted while the test is on-going).

5.2.5 Termination of test

If during the test run, the machine stops due to major component breakdown or malfunctions, the test shall be terminated by the test engineer.

5.2.6 Operation of the peanut sheller

The sheller shall be operated at the recommended speed and feed rate of the manufacturer. The same feeding rate recommended by the manufacturer shall be maintained during the test run. After the test run, the shelling area shall be cleaned and then prepared for the next trial.

5.2.7 Test trial.

A minimum of three test trials, with duration of at least 15 minutes per trial, shall be adopted.

5.2.8 Sampling

5.2.8.1 Sampling procedures for test materials

The conditions of crop, such as: variety, size of pod and kernel, number of kernel per pod, kernel-pod ratio, moisture content of kernel and shell, and damaged kernel and foreign matter; to be used in each test trial shall be taken using "representative samples" which represent the different condition of the harvested peanut on the pile. This is done by taking three 1.5 kg samples, each at the top, middle and bottom of the pile.

5.2.8.2 Sampling from Different Outlets

During each test trial, three sets of samples shall be randomly collected during the duration of the test trial from the different outlets to be analyzed in the laboratory for losses, purity and kernel quality.

5.2.8.2.1 Main kernel outlet

Using a plastic bag or an appropriate container, randomly collect three samples of at least 500 g each from the outlet.

5.2.8.2.2 Shell Outlet

In the collection of sample in this outlet, use a rectangular box-shaped nylon catch with a dimension of 0.5 m x 0.5 m x 1.5 m open at one end of the small side. Three samples shall be randomly collected from this outlet for a minimum duration of five seconds per collection. Separate the free kernel mixed with the shells and the kernels that are still attached to the shell. Put them in separate containers and label them as separation loss and unshelled loss, respectively.

5.2.8.2.3 Fan Outlet

During the test, three samples shall be randomly taken from the fan outlet for duration of at least 15 seconds per collection by using nylon net with a dimension of 1.5 m x 1.0 m held by two persons at both ends. These samples shall be placed in appropriate containers and labeled as blower loss.

5.2.8.3 Collection of scattered kernels

For testing purposes, scattered kernels shall be gathered since these kernels are part of the total kernel input. Spread canvas sheets on the shelling floor area to catch these kernels after each trial. Placed the collected kernels in appropriate containers and label them as scattered kernels.

Provisions shall be provided for the collection of scattered kernels with maximum distance of 1.0 m away from the base of the machine.

5.2.8.4 Handling of samples

All samples to be taken to the laboratory shall be placed in appropriate containers and properly labeled. If the samples are not to be immediately analyzed they should be air-dried and if necessary, treat samples in order to prevent the samples from possible damage. If the sample is to be used for determining moisture content, it must be kept in dry and airtight containers.

5.2.9 Data collection

5.2.9.1 Duration of test

The duration of each test trial shall start with the feeding of the materials into the intake hopper and ends after the last discharge from the main outlet.

5.2.9.2 Noise level

The noise emitted by the machine shall be measured using a noise level meter at the location of the feeder and bagger. The noise shall be taken approximately 50 mm away from the ear level of the operators and baggers.

5.2.9.3 Speed of components

The speed of the rotating shafts of the major components of the peanut sheller shall be taken using a tachometer.

NOTE Measurements shall be taken with and without load for sub-clauses 5.2.9.2 and 5.2.9.3 as specified in Annex C. Measurement with load shall be randomly taken during the duration of each test trial.

5.2.9.4 Air velocity

The air velocity generated by the shelling fan, with or without load, shall be taken using an air velocity meter measured in m/s.

5.2.9.5 Fuel/Power consumption

Before the start of each test trial, the fuel tank shall be filled to its capacity. After each test trial the tank shall be refilled using graduated cylinder. The amount of refueling is the fuel consumption for the test. When filling up the tank, keep the tank horizontal so as not to leave empty space in the tank. In case an electric motor is used as a primemover, a power meter shall be used to measure electric energy consumption.

5.2.9.6 Data recording and observations

Record sheet for all data and information during the test is given in Annex C.

6 Laboratory Analysis

Laboratory analysis shall be made to determine the moisture content of kernel and shell, kernel-pod ratio, purity, cracked and broken kernel and losses (blower, separation, unshelled and scattering). The laboratory test data sheet to be used is given in Annex D.

6.1 Measurement of moisture content

6.1.1 Manually remove all foreign matter from the sample. Obtain three representative samples weighing at least 100 g each for each test trial.

6.1.2 From the samples, separate the kernels and shell manually. Place each portion in separate moisture can. The moisture can shall be sealed to ensure that no moisture is lost or gained by the sample between the time it was collected and when it is weighed. Record the initial weight.

6.1.3 Oven dry kernels and shell in separate moisture can in an oven with temperature of 100 °C ± 3 °C for 72h.

6.1.4 On removing the samples from the oven, the moisture can should be placed in a desiccator and allowed to cool to the ambient temperature of the balance.

6.1.5 Weigh the moisture can plus the dried sample. Record the final weight of kernel and shell separately.

6.1.6 Calculate the percent shell/kernels and moisture content of shell/kernel using the following equations:

$$\text{A. Percent shells} = \frac{\text{Initial mass of shells, g}}{\text{Initial mass of pods, g}} \times 100$$

$$\text{B. Percent kernels} = \frac{\text{Initial mass of kernels, g}}{\text{Initial mass of pods, g}} \times 100$$

$$\text{C. Shell moisture content, \% wet basis} = \frac{\text{Loss in mass of shells, g}}{\text{Initial mass of shells, g}} \times 100$$

$$\text{D. Kernel moisture content, \% wet basis} = \frac{\text{Loss in mass of kernels, g}}{\text{Initial mass of kernels, g}} \times 100$$

6.1.7 Calculate moisture content of whole pod:

$$\text{Pods moisture content, \% wet basis} = \frac{(D \times B) + (C \times A)}{100}$$

6.2 Measurement of kernel and pod dimensions and weight

This shall be taken using at least ten representative samples of kernel and pod, and measure the length, diameter and weight.

6.3 Measurement of kernel-pod ratio

In measuring the kernel-pod ratio, randomly take three-100 pod representative samples from the test materials. For each sample, manually shell the pods from the shell. Determine the weight of the kernel and shell separately. Record and calculate the kernel-pod ration using the formula in Annex E1. The average of the three samples shall be taken as the kernel-pod ratio.

6.4 Purity Determination

Take three 500 grams samples from the main kernel outlet. Clean the kernels to remove the impurities and other foreign matters, the clean kernel shall be weighed and recorded. The percent purity is calculated using the formula in Annex E4.

6.5 Determination of Losses

6.5.1 Blower loss

Three samples taken from the fan outlet shall be cleaned and weighed. The total weight of the clean kernels and the total time of collection shall be recorded for the computation of blower loss (see Annex E5.2).

6.5.2 Separation loss

Three samples taken at the shell outlet with loose kernels mixed with the shell shall be cleaned and weighed. The total time of collection of the three samples shall be taken and recorded for the computation of separation loss (see Annex E5.3).

6.5.3 Unshelled loss

Unshelled kernels collected at the shell outlet shall be hand shelled and weighed. The total weight and time of collection shall be taken and recorded for the computation of unshelled loss (see Annex E5.4).

6.5.4 Scattering loss

Collected kernels scattered around the sheller after each trial shall be cleaned and weighed for the determination of scattering loss. (See Annex E5.5)

6.6 Determination of net percent cracked kernels

Three 100-kernel samples each from manually shelled and machine shelled kernels shall be taken for analysis. These kernels shall be inspected for the presence of fissures. The net percent cracked kernels shall be taken as the difference between the values obtained from the manual and machine shelled kernel samples (see Annex E8).

6.7 Determination of percent mechanically damaged kernels

Three 100-gram samples from machine shelled kernels shall be taken for analysis. Separate those kernels that were broken or crushed and weigh. Compute for the percent broken kernels (see Annex E9).

7 Formula

The formulas to be used during calculations and testing are given in Annex E.

8 Test Report

The test report shall include the following information in the order given:

8.1 Name of testing agency

8.2 Test report number

8.3 Title

8.4 Summary

8.5 Purpose and scope of test

8.6 Methods of test

8.7 Description of the machine

8.7.1 Fig. 1 – Material flow diagram

8.7.2 Fig. 2 – Power transmission system

8.7.3 Fig. 3 – Arrangements of shelling elements on the cylinder

8.7.4 Table 1 – Machine specifications

8.8 Result of test

8.8.1 Table 2 –Performance test data

8.9 Observations (include pictures)

8.10 Name, signature and designation of test engineers

Annex A
(informative)

Minimum List of Field and Laboratory Test Equipment and Materials

A.1	Equipment	Quantity
A.1.1	**Field**	
A.1.1.1	Grain moisture meter (capacitance or conductance type) Range: 6% to 40%	1
A.1.1.2	Air velocity meter Range: 0 m/s to 30 m/s	1
A.1.1.3	Tachometer (contact or photoelectric type) Range: 0 rpm to 5,000 rpm	1
A.1.1.4	Noise level meter Range: 30 db (A) to 130 db (A)	1
A.1.1.5	Timers Range: 60 minutes; Accuracy: 1/10 sec	2
A.1.1.6	Measuring tape Capacity: 5 m	1
A.1.1.7	Camera	1
A.1.1.8	Weighing scale Capacity: 100 kg; Scale divisions: 0.5 kg	1
A.1.1.9	Graduated cylinder Capacity: 500 mL	1
A.1.2	**Laboratory**	
A.1.2.1	Weighing scale (Sensitivity: 0.1 g)	1
A.1.2.2	Magnifying lens (minimum of 10 magnifications)	1
A.1.2.3	Grain sample cleaner	1
A.1.2.4	Caliper	1
A.1.2.5	Aluminum moisture can	18
A.1.2.6	Dessicator	1
A.2	**Materials**	
A.2.1	Field	
A.2.1.1	Canvass sheet (4 m x 6 m)	1
A.2.1.2	Nylon catch bag (0.5 m x 0.5 m x 1.5 m)	1
A.2.1.3	Nylon net (1.5 m x 1.0 m)	1
A.2.1.4	Sample bags	45
A.2.1.5	Labels/Tags which include	45
A.2.1.5.1	Date of test	
A.2.1.5.2	Machine on test	
A.2.1.5.3	Sample source	
A.2.1.5.3	Variety	
A.2.1.5.4	Trial number	

Annex B
(informative)

Specifications of Peanut Sheller

Name of Applicant (or Distributor) : _____
Address : _____
Telephone No. : _____
Name of Factory/Distributor : _____
Address : _____

GENERAL INFORMATION

Brand/Model : _____ Make : _____
Serial No. : _____ Classification : _____
Date Manufactured: _____

Items to be inspected

ITEMS	Manufacturer's Specifications	Verification by the Testing Agency
B.1 Overall dimensions and weight of sheller		
B.1.1 length, mm		
B.1.2 width, mm		
B.1.3 height, mm		
B.1.4 Weight of the machine without primemover, kg		
B.2 Rated output capacity, kg/h		
B.3 Recommended cylinder speed, rpm		
B.4 Type of power transmission system		
B.4.1 Engine to _____		
B.4.2 Cylinder shaft to _____		
B.4.3 Fan shaft to _____		
B.4.4 Oscillating sieve/screen to _____		
B.4.5 Others (specify)		
B.5 Shelling cylinder		
B.5.1 Type		
B.5.2 Dimension (L x D), mm		
B.5.3 Cylinder teeth		
B.5.3.1 Type		
B.5.3.2 Size		
B.5.3.3 Number/row		
B.5.3.4 No. of rows		
B.5.3.5 Arrangement		
B.5.3.6 Means of attachment		
B.5.3.7 Material		
B.5.3.8 Others		
B.5.4 Material		

ITEMS	Manufacturer's Specifications	Verification by the Testing Agency
B.6 Fan		
B.6.1 Type		
B.6.2 No. of units		
B.6.3 Impeller		
B.6.3.1 Material		
B.6.3.2 Number of blades		
B.7 Oscillating screen		
B.7.1 Dimension (L x W), mm		
B.7.2 Size of perforations, mm		
B.7.3 Length of stroke, mm		
B.7.4 Material		
B.8 Concave component		
B.8.1 Overall diameter, mm		
B.8.2 Clearance		
B.8.2.1Maximum, mm		
B.8.2.2Minimum, mm		
B.8.3 Material		
B.9 Hopper (if available)		
B.9.1 Location		
B.9.2 Material		
B.9.3 Feature		
B.11 Feeding table (if available)		
B.11.1 Dimensions (L x W), mm		
B.11.2 Height from the ground, mm		
B.11.3 Orientation		
B.11.4 Mode of attachment		
B.11.5 Material		
B.12 Transport device		
B.12.1 Type		
B.12.2 Size		
B.13 Safety device(s), if any		
B.14 Discharge device		
B.15 Adjustment(s)		
B.16 Other special features		
B.17 Primemover		
B.17.1 Engine		
B.17.1.1 Brand		
B.17.1.2 Model		
B.17.1.3 Serial number		
B.17.1.4 Type (stroke/ignition)		
B.17.1.5 Rated power, kW		
B.17.1.6 Rated speed, rpm		
B.17.1.7 Cooling system		
B.17.1.8 Starting system		
B.17.1.9 Weight, kg		
B.17.2 Electric motor		

ITEMS	Manufacturer's Specifications	Verification by the Testing Agency
B.17.2.1 Brand		
B.17.2.2 Model		
B.17.2.3 Rated power, kW		
B.17.2.4 Rated speed, rpm		
B.17.2.5 Weight, kg		

B.18 Illustration of transmission system

Annex C
(informative)

Performance Test Data Sheet

Test Trial No. : _____ Date : _____
Test Engineers: _____ Location: _____

Items to be inspected

ITEMS	Trial 1	Trial 2	Trial 3	Ave.
C.1 Crop condition				
C.1.1 Kind/variety				
C.1.2 Days after harvest				
C.1.3 Source				
C.1.4 Size of pod				
C.1.4.1 Length, mm				
C.1.4.2 Diameter, mm				
C.1.4.3 Weight, g				
C.1.5 Size of kernel				
C.1.5.1 Length, mm				
C.1.5.2 Diameter, mm				
C.1.5.3 Weight, g				
C.1.6 Kernel-pod ratio				
C.2 Performance test				
C.2.1 Speed of components, rpm				
C.2.1.1 Prime mover				
C.2.1.1.1 Without load				
C.2.1.1.2 With load				
C.2.1.2 Shelling cylinder shaft				
C.2.1.2.1 Without load				
C.2.1.2.2 With load				
C.2.1.3 Fan shaft				
C.2.1.3.1 Without load				
C.2.1.3.2 With load				
C.2.1.4 Oscillating screen shaft				
C.2.1.4.1 Without load				
C.2.1.4.2 With load				
C.2.2 Fan air velocity, m/s				
C.2.2.1 Without load				
C.2.2.2 With load				
C.2.3 Noise level, db(A)				
C.2.3.1 Feeder				
C.2.3.1.1 Without load				
C.2.3.1.2 With load				
C.2.3.2 Bagger				
C.2.3.2.1 Without load				
C.2.3.2.2 With load				

ITEMS	Trial			
	1	2	3	Ave.
C.2.4 Shelling time, min				
C.2.5 Shelled kernel, kg				
C.2.6 Shelling capacity, kg/h				
C.2.7 Fuel time, min				
C.2.8 Fuel consumed, L				
C.2.9 Fuel consumption, L/h				
C.2.10 Minimum labor requirements				

C.3 Rate the following observations:

Items	Rating*				
	1	2	3	4	5
C.3.1 Ease of loading					
C.3.2 Ease of cleaning parts					
C.3.3 Ease of adjusting and repair of parts					
C.3.4 Ease of collecting output					
C.3.5 Ease of transporting the machine					
C.3.6 Safety					
C.3.7 Vibration					

* 1 – Very Good
2 – Good
3 – Satisfactory
4 – Poor
5 – Very Poor

C.4 Other Observations:

_____

_____

_____

Annex D
(informative)

Laboratory Grain Analysis Data Sheet

Machine Tested : _____ Analyzed by : _____
Date of Test : _____ Date Analyzed: _____

D.1 Crop Conditions

D.1.1 Moisture Content, (% w.b.)

D.1.1.1 Kernel

		Average	

D.1.1.2 Shell

		Average	

D.1.2 Kernel-pod ratio (100 pods)

Sample No.	Weight of Pod g			Weight of Kernel g			Kernel-pod ratio		
	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
1									
2									
3									
...									
100									
Average									

D.2 Kernel Analysis

D.2.1 Purity Determination

Initial Weight of Samples (uncleaned) = 500 gms

ITEMS	Trial 1				Trial 2				Trial 3				Gen. Ave.
	1	2	3	Ave.	1	2	3	Ave.	1	2	3	Ave.	
Cleaned (g)													
Purity (%)													

D.2.2 Loss Determination

Trial	Blower Loss		Separation Loss		Unshelled Loss		Scattering Loss	
	Duration:		Duration:		Duration:		Duration:	
	Sample Wt. g	Total kg	Sample Wt g	Total kg	Sample Wt. g	Total kg	Sample Wt. g	Total kg
1- a								
b								
c								
Ave.								
2- a								
b								
c								
Ave.								
3- a								
b								
c								
Ave.								
Gen. Ave.								

D.2.3 Shelling Efficiency/Recovery Determination

Trial No.	Blower Loss		Separation Loss		Unshelled Loss		Scattering Loss		Total	
	Wt.	%	Wt.	%	Wt.	%	Wt.	%	Output kg	Input kg
1										
2										
3										
Average										

Annex E
(informative)

Formula Used During Calculations and Testing

E.1 Kernel-pod ratio

$$K_r = \frac{W_k}{W_p}$$

where:

K_r = Kernel-pod ratio
W_k = Weight of kernel, g
W_p = Weight of the pod, g

E.2 Fuel consumption

$$F_c = \frac{F_l}{T_o}$$

where:

F_C = Fuel consumption, L/h
F_l = Amount of fuel consumed, L
T_O = Time of operation, h

E.3 Shelling Capacity

E.3.1 Actual capacity

$$C_a = \frac{W_c}{T_o}$$

where:

C_a = Actual shelling capacity, kg/h
W_C = Weight of shelled kernel, kg
T_O = Duration of operation, h

E.3.2 Corrected capacity (at 100% purity, 14% moisture content)

$$C_c = \frac{100 - MC_o}{100 - MC_m} P\ C_a$$

where:

C_C = Corrected capacity, kg/h
MC_O = Observed moisture content, %
MC_m = Kernel moisture content, at 10%
P = Kernel purity, %
C_a = Actual capacity, kg/h

E.4 Purity

$$P = \frac{W_c}{W_u} \times 100$$

where:

P = Purity, %
W_u = Weight of uncleaned kernel, g
W_C = Weight of cleaned kernel, g

E.5 Losses

E.5.1 Summation of all losses

L_t = Blower loss + Separation loss + Unshelled loss + Scattering loss

where:

L_t = Summation of all losses, kg

E.5.2 Blower loss

Amount

$$B_l = \frac{W_b}{T_c} T_o$$

where:

B_l = Blower loss, kg
W_b = Weight of blown clean kernel, kg
T_c = Duration of collection, h
T_o = Duration of operation, h

Percentage

$$B_l = \frac{W_l}{W_c + L_t} \times 100$$

where:

B_l = Blower loss, %
W_l = Weight of blown clean kernel, kg
W_c = Weight of cleaned shelled kernel, kg
L_t = Summation of all losses, kg

E.5.3 Separation loss

Amount

$$S_l = \frac{W_s}{T_c} T_o$$

where:

S_l = Separation loss, kg
W_s = Weight of separated clean kernel, kg
T_c = Duration of collection, h
T_o = Duration of operation, h

Percentage

$$S_l = \frac{W_s}{W_c + L_t} \times 100$$

where:

S_l = Separation loss, kg
W_s = Weight of separated clean kernel, kg
W_c = Weight of cleaned shelled kernel, kg
L_t = Summation of all losses, kg

E.5.4 Unshelled loss

Amount

$$U_l = \frac{W_u}{T_c} T_o$$

where:

U_l = Unshelled loss, kg
W_u = Weight of unshelled clean kernel, kg
T_c = Duration of collection, h
T_o = Duration of operation, h

Percentage

$$U_l = \frac{W_u}{W_c + L_t} \times 100$$

where:

U_l = Unshelled loss, kg
W_u = Weight of unshelled clean kernel, kg
W_c = Weight of cleaned shelled kernel, kg
L_t = Summation of all losses, kg

E.5.5 Scattering loss

Amount

$$Sc_l = \frac{W_{sc}}{T_c} T_o$$

where:

Sc_l = Scattering loss, kg
W_{sc} = Weight of scattered clean kernel, kg
T_c = Duration of collection, h
T_o = Duration of operation, h

Percentage

$$Sc_l = \frac{W_{sc}}{W_c + L_t} \times 100$$

where:

Sc_l = Scattering loss, %
W_{sc} = Weight of scattered clean kernel, kg
W_c = Weight of cleaned shelled kernel, kg
L_t = Summation of all losses, kg

E.6 Shelling Efficiency

$$S_e = \frac{W_c + B_l + S_l + Sc_l}{W_c + L_t} \times 100$$

or

$S_e = 100\% - U_l$

where:

S_e = Shelling efficiency, %
W_c = Weight of cleaned shelled kernel, kg
B_l = Blower loss, kg
S_l = Separation loss, kg
Sc_l = Scattering loss, kg
L_t = Summation of all losses, kg
U_l = Unshelled loss, kg

E.7 Shelling Recovery

$$S_r = \frac{W_c}{W_c + L_t} \times 100$$

where:

S_r = Shelling recovery, %
W_c = Weight of cleaned shelled kernel, kg
L_t = Summation of all losses, kg

E.8 Cracked kernel

$$C_k = \frac{n_c}{N_k} \times 100$$

where:

C_k = Cracked kernel, %
n_c = Number of cracked kernels
N_k = 100 kernel sample

E.9 Mechanically damaged kernel

$$D_k = \frac{W_d}{N_g} \times 100$$

where:

D_k = Mechanically damaged kernel, %
W_d = Weight of mechanically damaged kernels, g
N_g = 100 gram sample